CHAPTER 3

AC POWER DISTRIBUTION SYSTEM

Almost every function performed aboard a naval ship depends upon electric power for its accomplishment From the launching of missiles against an aggressive force to baking bread for lunch, electric power is vital to a ship's ability to accomplish its mission.

The ship's service electric plant is equipment that takes the mechanical power of a prime mover and converts it to electrical energy. The prime mover may be driven by steam, gas turbine, diesel, or motor. The mechanical energy of the prime mover is converted to electrical energy in the ship's service generators. These generator sets supply power to the ship's ac power distribution system for further distribution to the various electrical loads throughout the ship.

The ac power distribution system aboard ship consists of the following:

- Ac power plant.
- Switchboards that distribute the power.
- The equipment that consumes the power.

The power distribution system is comprised of the following:

- Ship's service power distribution system.
- Emergency power distribution system.
- Casualty power distribution system.

ELECTRICAL DISTRIBUTION SYSTEM

The electrical distribution system is the link between the ship's source of electrical power and the ship's electrical loads. Power is normally supplied from the ship's own generators but can be supplied from an external source through the shore power cables.

Most ac power distribution systems in naval ships are 450-volt, three-phase, 60-Hertz, three- wire systems.

Bus ties interconnect the ship's service generator and distribution switchboards so any switchboard can be connected to feed power from the generators to one or more of the other switchboards allowing the generators to operate in parallel.

In large installations (fig. 3-1), power from the generators goes through distribution switchboards or

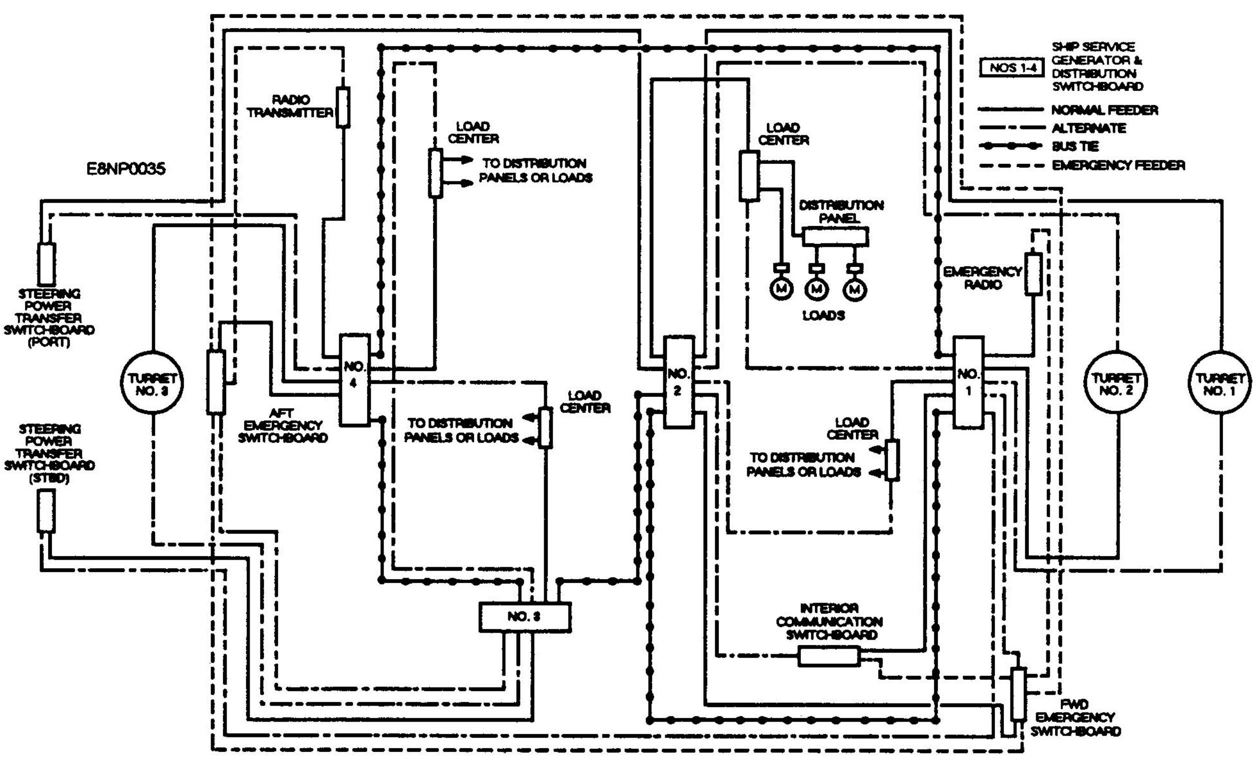


Figure 3-1.-Power distribution in a large combatant ship.

switchgear groups to the load centers, through distribution panels, and on to the loads. Distribution may also be direct from the load centers to some loads.

On some large ships, such as aircraft carriers, a system of zone control of the ship's service and emergency power distribution system is provided. The system sets up several vertical zones that contain one or mere load center switchboards supplied through bus feeders from the ship's service switchgear group. A load center switchboard supplies power to the electrical loads within the electrical zone in which it is located. Thus, zone control is provided for all power within the electrical zone. An emergency switchboard may supply mere than one zone.

In small installations (fig. 3-2), the distribution panels may or may not be fed directly from the generator and distribution switchboards.The distribution panels and load centers, if installed, are located centrally with respect to the loads they feed. 'his arrangement simplifies the installation and requires less weight, space, and equipment than if each load were connected to a switchboard.

CIRCUIT MARKINGS

All distribution panels and bus transfer equipment have cabinet information plates. These plates contain the following information in the order listed

1. The name of the space, apparatus, or circuits served.
2. The service (power, lighting, electronics) and basic location number.
3. The supply feeder number.

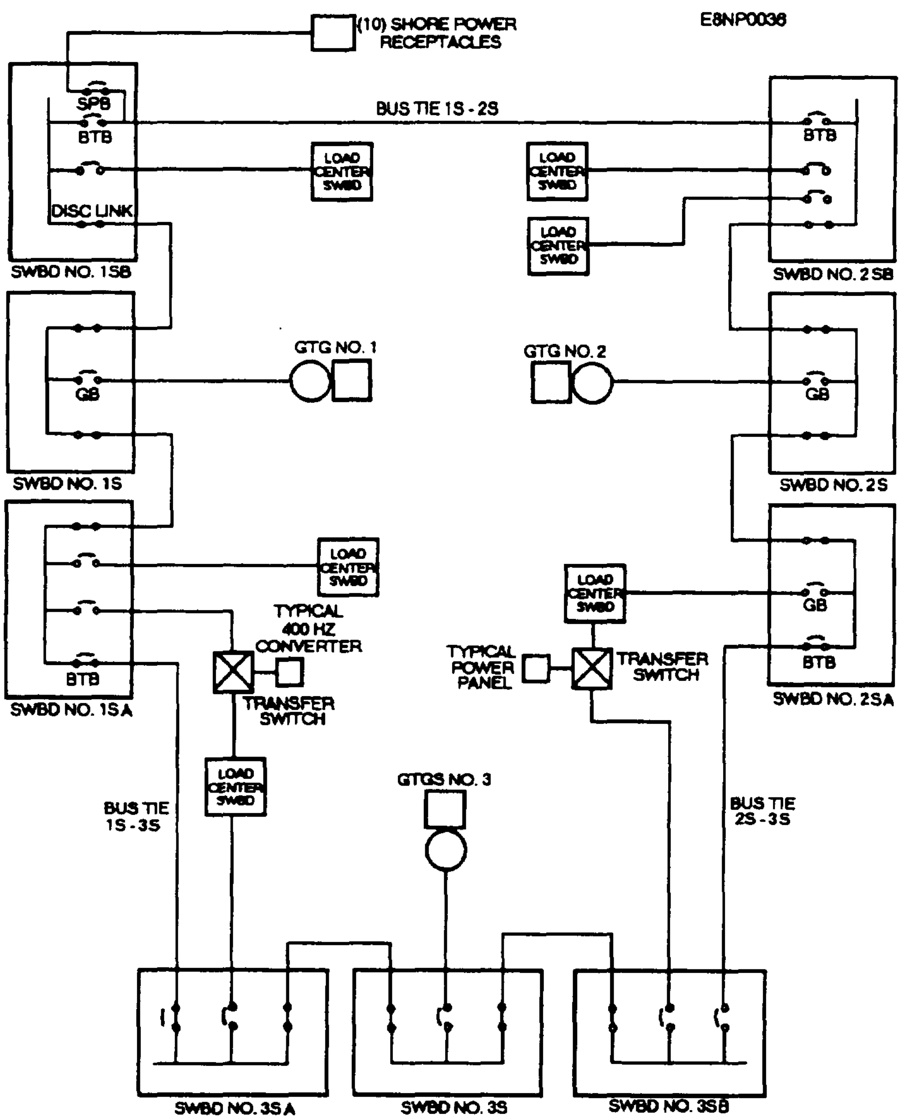


Figure 3-2.-Power distribution in a gas-turbine powered DDG.

CREW LIVING SPACE, FRAMES XX - XX
FIRST PLATFORM
LIGHTING PANEL 4-108-2
2S-4L-(4-103-2)

If a panel contains two or more sets of buses and each set is supplied by a separate feeder, the number of each feeder will be indicated on the identification plate.

Distribution panels have circuit information plates next to the handle of each circuit breaker or switch. These plates contain the following information in the order listed:

1. The circuit number.
2. The name of the apparatus or circuit controlled.
3. The location of the apparatus or space served.
4. The circuit breaker element or fuse rating.

Vital circuits are shown by red markers attached to circuit information plates. Information plates for circuit breakers supplying circle W and circle Z class ventilation systems contain, in addition to the red marker, the class designation of the ventilation system supplied. Information plates without markings are provided for spare circuit breakers mounted in distribution panels. Panel switches controlling circuits that are de-energized during darkened ship operations are marked DARKENED SHIP. The ON and OFF position of these switches are marked LIGHT SHIP and DARKENED SHIP, respectively.

Circuit information plates are provided inside fuse boxes (next to each set of the fuses). They show the circuit controlled, the phases or polarity, and the ampere rating of the fuse.

PHASE SEQUENCE

The phase sequence in naval ships is ABC; that is, the maximum positive voltages on the three phases are reached in the order A, B, and C (fig. 3-3). Phase sequence determines the direction of rotation of three-phase motors. Therefore, a reversal of the phase sequence could cause damage to loads, especially pumps, driven by three-phase motors. The phase sequence of the power supply throughout a ship is always ABC (regardless of whether power is supplied from any of the switchboards or from the shore power connection) to ensure that three-phase, ac motors will always run in the correct direction.

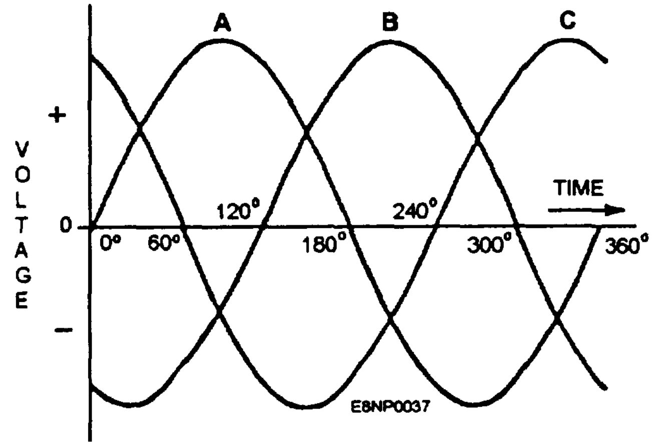


Figure 3-3.-Sine curve for three-phase circuit.

Phase identification is denoted by the letters *A*, *B*, and C in a three-phase system. Switchboard and distribution panel bus bars and terminals on the back of switchboards are marked to identify the phase with the appropriate letters, *A*, *B*, or C. The standard arrangement of phases in power and lighting switchboards, distribution panels, feeder distribution boxes, feeder junction boxes, and feeder connection boxes is in the order A, B, and C from top to bottom, front to back or right to left when facing the front of the switchboard, panel, or box, and left to right when facing the rear of the switchboard, panel, or box.

BUS TRANSFER SWITCHES

Bus transfer equipment is used to provide two sources of power to equipment that is vital to the ship. This vital equipment is that equipment needed to operate safely or could cause the ship to become disabled if it becomes de-energized.

Depending upon the application, the transfer from one source to another may be done manually, by a manual bus transfer switch, or automatically by an automatic bus transfer switch.

MANUAL BUS TRANSFER (MBT) SWITCHES

When normal power to vital equipment is lost, power must be restored as soon as possible to ensure the safety of the ship. MBTs maybe used to switch from normal to alternate or emergency power for those loads that draw a large starting current or for which some condition must be met before energizing. A good example of this would be HF radio equipment, if power would be automatically reapplied after a sudden loss, major damage would occur to the transmitter.

After a sudden loss of power, having a manual transfer of the power source will ensure all conditions are met before energizing the equipment. (See figure 3-4.)

AUTOMATIC BUS TRANSFER (ABT) SWITCHES

ABTs are used to provide two sources of power to those loads that MUST be re-energized as soon as possible after a sudden loss of normal power. Some examples would be lighting in main engineering spaces, ship's steering motors and controls, motor-driven fuel pumps, and lubricating oil pumps.

SHIP'S SERVICE SWITCHBOARDS

Aboard modem Navy vessels there are three distinct groups or shipsets of distribution switchboards. A shipset of main power distribution switchboards consists of three groups, each group being comprised of three units. Figures 3-5 to 3-7 show the switchboards that comprise shipset 1S.

The units, physically separated and connected by cables, form a switchgear group. This physical separation of sections provides greater protection from damage since it is less likely more than one unit can be damaged by one hit in battle. It also provides a means for removing a damaged section for repairs or replacement.

Switchboards provide three distinct functions aboard ship:

- Distribution of 450-volt, 3-phase, 60-Hz power
- Protection of distribution circuits
- Control, monitoring, and protection of the generator sets

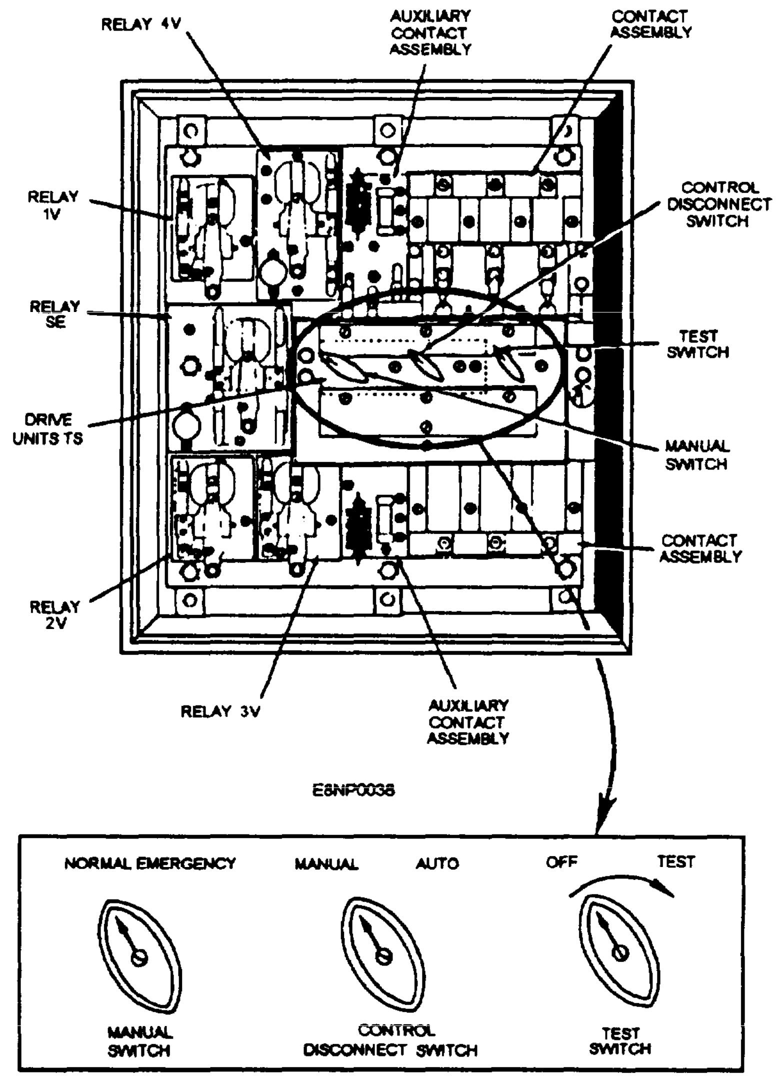


Figure 3-4.-A pictorial view of the A-2 ABT.

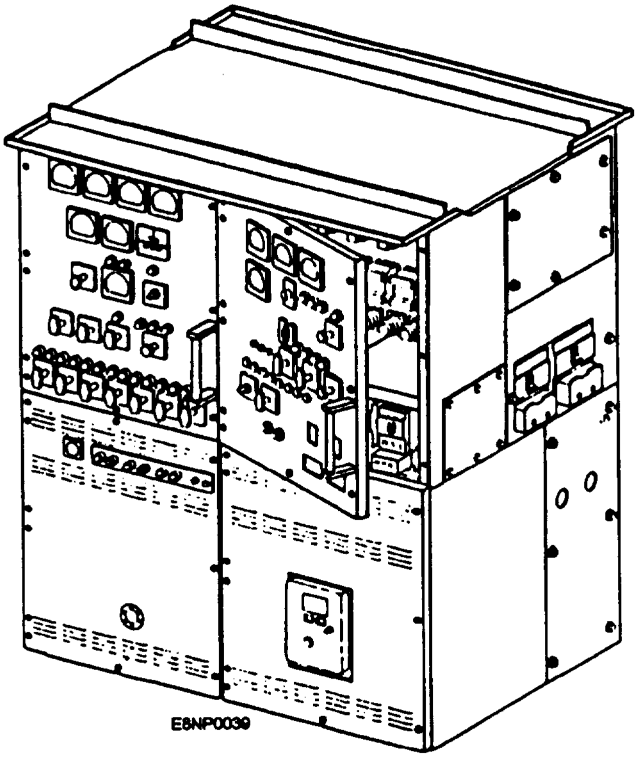


Figure 3-5.-1S ship's service switchboard.

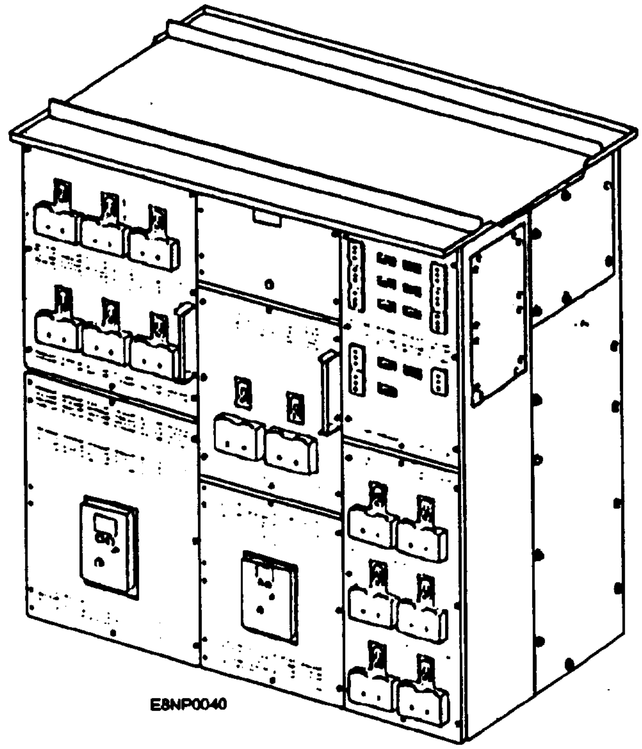


Figure 3—6.-1SA Ship's switchboard.

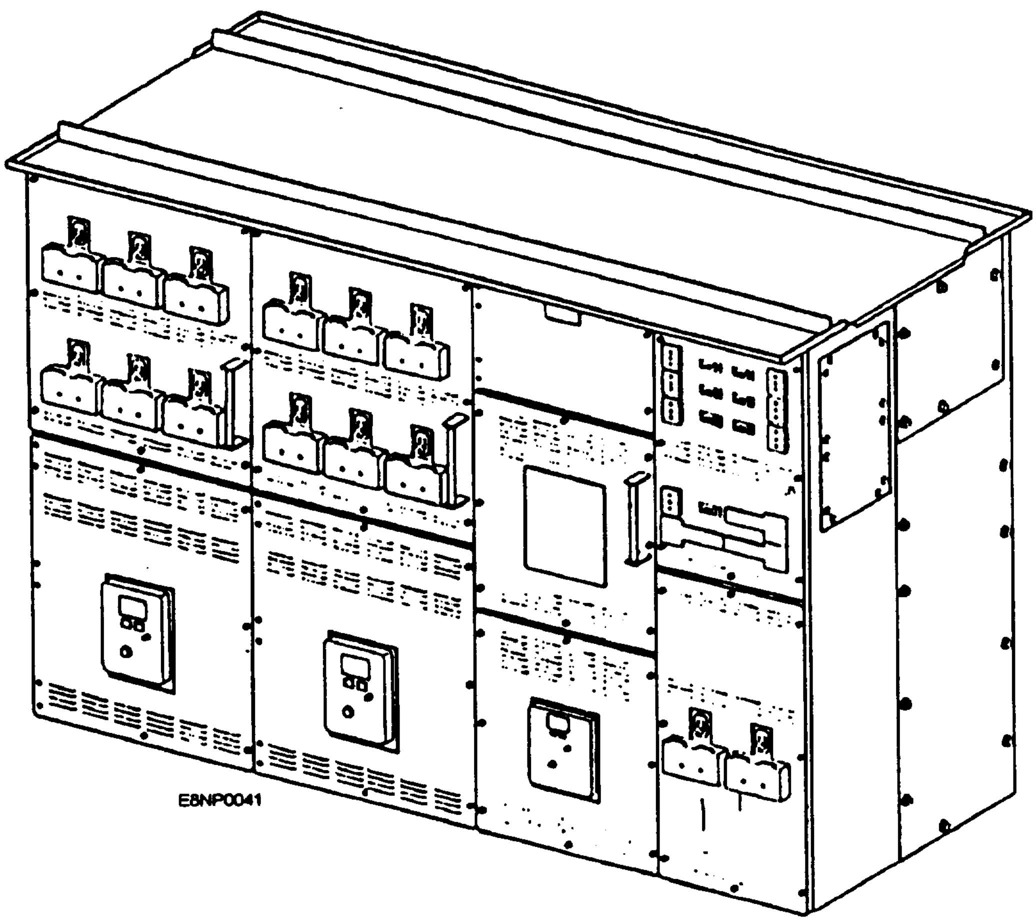


Figure 3-7.-1SB ship's service switchboard.

CAPABILITIES

Each switchboard group is an operationally independent system, capable of monitoring and controlling an associated generator.

Operated as an independent system, a switchboard is capable of distributing the power produced by the associated generator to equipment and zones fed by the switchboard bus. Operated in parallel with either one or both of the other groups, power can be supplied to the entire ship service load.

DESCRIPTION

Power is produced by the generators, input to the switchboards through the generator circuit breakers, and distributed to the various ship's loads via feeder breakers and load centers.

Control and monitoring of the ship's service power is accomplished by the various manual, remote, and automatic control functions associated with the switchboards. In addition, the metering and indications used to maintain proper power plant performance give the electrician on watch the status of the power plant at any given time.

The distribution system is protected from damage by the various mechanical and electrical devices used to interrupt the flow of electricity, either by command or automatically, should a problem arise.

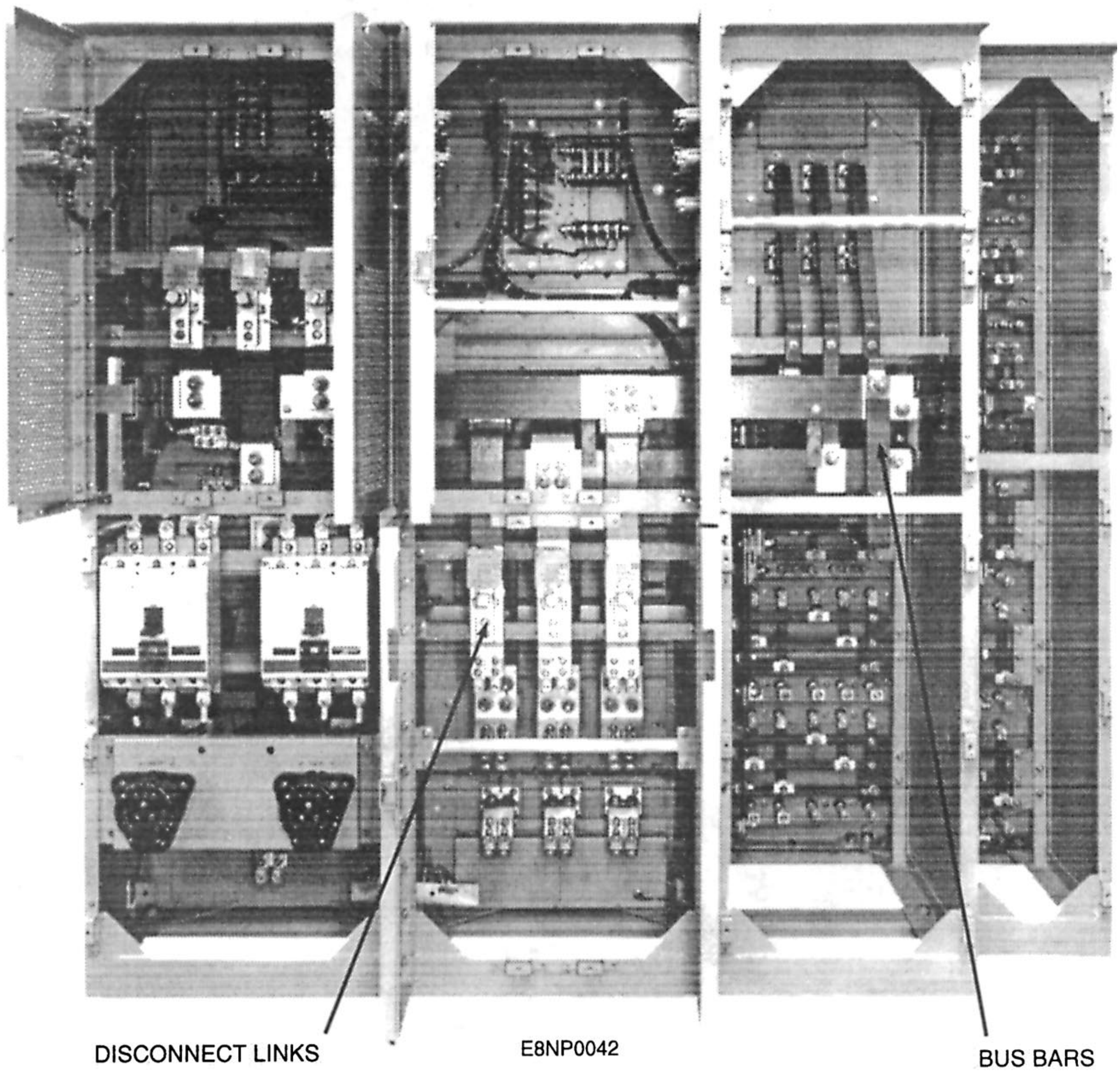


Figure 3-8.-Rear view of a switchboard showing bus bars and disconnect links.

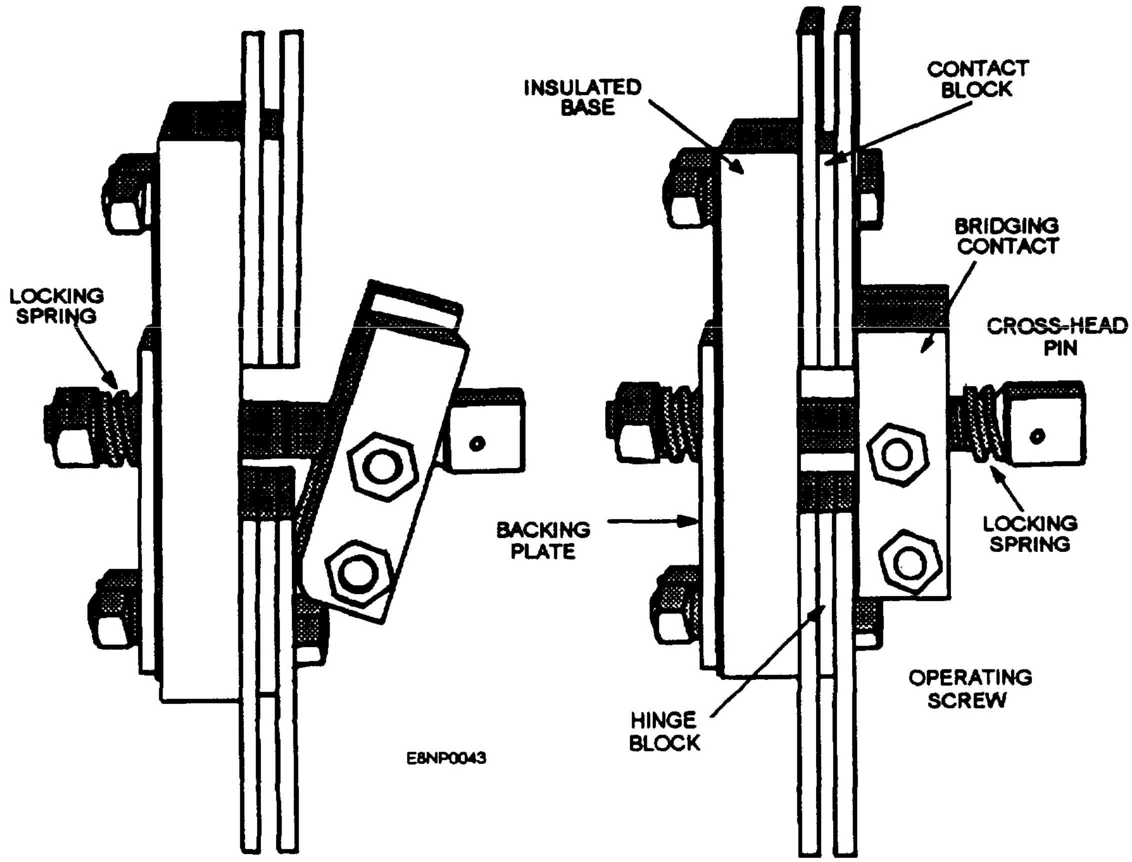


Figure 3-9.-Disconnect links.

The switchboards shown in figures 3-5,3-6, and 3-7 are representative of the found on most gas-turbine powered ships today. These switchboards use sheet steel panels or enclosures from which only the meters and the operating handles protrude to the front. Distribution of the generated power begins with the switchboard. These switchboards can be connected together through bus tie circuit breakers to form a continuous loop. This allows any two of the three gas turbine generator sets (GTGS's) to supply the demand for power, while the third can be set up to start automatically in the event of a power loss. (See figure 3-8.)

Each of the switchboard units of a group are connected together through disconnect links (fig. 3-9). By removing the links between any two of the switchboards, repairs or replacement of parts may be accomplished without interfering with the operation of the other units.

GROUND DETECTOR CIRCUITS

A set of three ground detector lamps (fig. 3-10) is connected through transformers to the main bus of each ship's service switchgear group. It provides you with a means to check for grounds on any phase of the three-phase system.

To check for a ground, turn switch S on and observe the brilliancy of the three lights. If the lights are equally bright, all lights are receiving the same voltage, and no ground exists. If lamp A is dark and lamps B and C are bright, phase A is grounded. In this case, the primary of the transformer in phase A is shunted to ground, and lamp A receives no voltage. Similarly, if lamp B is dark and lamps A and C are bright a ground exists on phase B. If lamp C is dark and lamps A and B are bright, a ground exists on phase C.

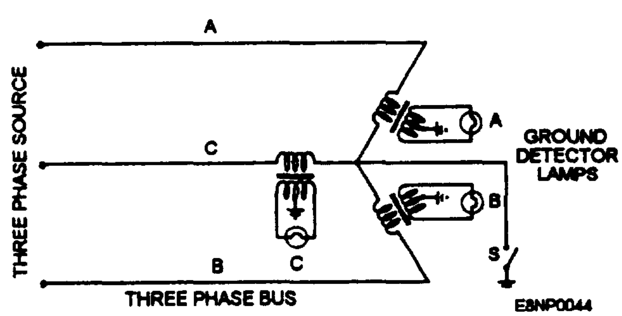


Figure 3-10.-An ac ground detector lamp circuit.

AC GENERATORS

Alternating-current generators produce most electric power used today. Ac generators are also used in aircraft and automobiles.

Ac generators come in many different sizes, depending on their intended use. For example, any one of the huge generators at Boulder Dam can produce millions of volt-amperes, while the small generators used on aircraft produce only a few thousand volt-amperes.

Regardless of their size, all generators operate on the same basic principle-a magnetic field cutting through conductors, or conductors passing through a magnetic field.

All generators have at least two distinct sets of conductors:

> A group of conductors in which the output voltage is generated known as the *armature winding.*

> A second group of conductors through which direct current is passed to obtain an electromagnetic field of fixed polarity known as the *field winding.*

Since relative motion is needed between the armature and field flux, ac generators are built in two major assemblies—the stator and the rotor (fig. 3-11).

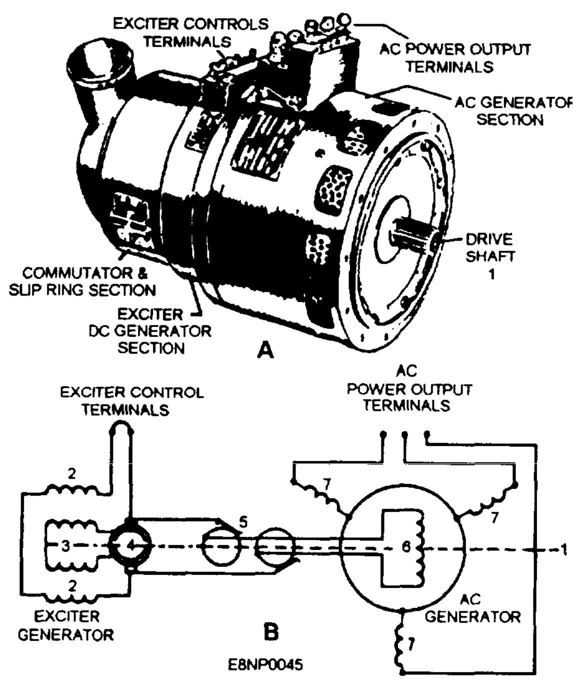


Figure 3-11.-An ac generator and schematic.

The rotor rotates inside the stator. It is driven by several commonly used power sources: gas or steam turbines, electric motors, and internal-combustion engines.

THREE-PHASE GENERATORS

A three-phase ac generator, as the name implies, has three single-phase windings spaced so that the voltage induced in each winding is 120° out of phase with the voltages in the other two windings. A schematic diagram of a three-phase stator showing all the coils becomes complex, and it is difficult to see what is actually happening. A simplified schematic diagram showing all the windings of a single phase lumped together as one winding is illustrated in figure 3-12, view A. The rotor is omitted for simplicity. The waveforms of voltage are shown to the right of the schematic. The three voltages are 120° apart and are similar to the voltages that would be generated by three single-phase ac generators whose voltages are out of phase by angles of 120°. The three phases are independent of each other.

Wye Connection

Rather than have six leads come out of the three-phase ac generator, one of the leads from each phase may be connected to form a common junction. The stator is then said to be wye, or star, connected. The common lead may or may not be brought out of the machine. If it is brought out, it is called the neutral. The simplified schematic (fig. 3-12, view B) shows a wye-connected stator with the common lead not brought out. Each load is connected across two phases in series. R_{AB} is connected across phases A and B in series; R_{AC} is connected across phases A and C in series; and R_{BC}

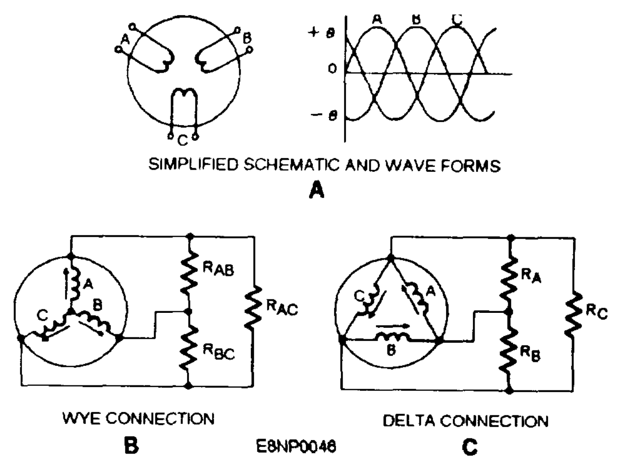


Figure 3-12.—Three-phase ac generator: A. Simplified schematic and wave forms; B. Wye connection; C. Delta connection.

is connected across phases B and C in series. Thus, the voltage across each load is larger than the voltage across a single phase. In a wye-connected ac generator, the three start ends of each single-phase winding are connected together to a common neutral point and the opposite, or finish, ends are connected to the line terminals, A, B, and C. These letters are always used to designate the three phases of a three-phase system, or the three line wires to which the ac generator phases comect.

A three-phase, wye-connected ac generator supplying three separate loads is shown in figure 3-13. When unbalanced loads are used, a neutral may be added as shown in the figure by the broken line between the common neutral point and the loads. The neutral wire serves as a common return circuit for all three phases and maintains a voltage balance across the loads. No current flows in the neutral wire when the loads are balanced. This system is a three-phase, four-wire circuit and is used to distribute three-phase power to shorebased installations. The three-phase, four-wire system is not used aboard ship, but it is widely used in industry and in aircraft ac power systems.

Delta Connection

A three-phase stator may also be connected as shown in figure 3-12, view C. This is called the delta connection. In a delta-connected ac generator, the start end of one phase winding is connected to the finish end of the third; the start of the third phase winding is connected to the finish of the second phase winding; and the start of the second phase winding is connected to the finish of the first phase winding. The three junction points are connected to the line wires leading to the load.

A three-phase, delta-connected, ac generator is depicted in figure 3-14. The generator is connected to a three-phase, three-wire circuit, which supplies a three-phase, delta-connected load at the right-hand end of the three-phase line. Because the phases are connected directly across the line wires, phase voltage

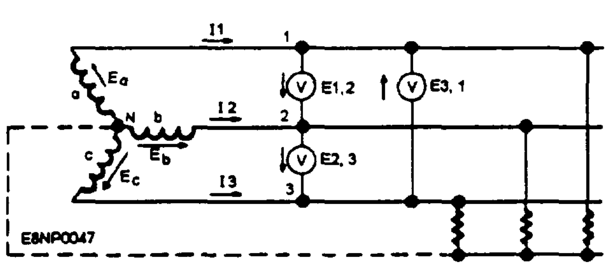


Figure 313.—Three-phase ac generatar showing neutral connection.

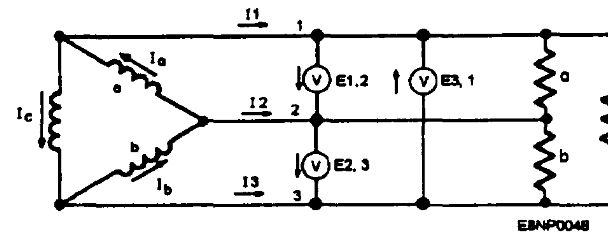


Figure 3-14.-Three-phase, delta-connected system.

is equal to line voltage. When the generator phases are properly connected in delta, no appreciable current flows within the delta loop when there is no external load connected to the generator. If anyone of the phases is reversed with respect to its correct connection, a short-circuit current flows within the windings of no load, causing damage to the windings.

TRANSFORMERS

A transformer is a device that has no moving parts and that transfers energy from one circuit to another by electromagnetic induction. The energy is always transferred without a change in frequency, but usually with changes in voltage and current. A step-up transformer receives electrical energy at one voltage and delivers it at a higher voltage. Conversely, a step-down transformer receives energy at one voltage and delivers it at a lower voltage. Transformers require little care and maintenance because of their simple, rugged, and durable construction. The efficiency of transformers is high. Because of this, transformers are responsible for the more extensive use of alternating current than direct current. The conventional constant-potential transformer is designed to operate with the primary connected across a constant-potential source and to provide a secondary voltage that is substantially constant from no load to full load.

Various types of small, single-phase transformers are used in electrical equipment. In many installations, transformers are used on switchboards to step down the voltage for indicating lights. Low-voltage transformers are included in some motor control panels to supply control circuits or to operate overload relays.

Instrument transformers include potential, or voltage, transformers and current transformers. Instrument transformers are commonly used with ac instruments when high voltages or large currents are to be measured.

Electronic circuits and devices employ many types of transformers to provide the necessary voltages for proper circuit operation, interstage coupling, signal amplification, and so forth. The physical construction of these transformers differs widely.

Power-supply transformers, used in electronic circuits, are single-phase, constant-potential transformers with either one or more secondary windings, or a single secondary with several tap connections. These transformers have a low volt-ampere capacity and are less efficient than large constant-potential power transformers. Most power-supply transformers for electronic equipment are designed to operate at a frequency of 50 to 60 Hz. Aircraft power-supply transformers are designed for a frequency of 400 Hz. The higher frequencies permit a saving in size and weight of transformers and associated equipment.

The typical transformer has two windings insulated electrically from each other. These windings are wound on a common magnetic core made of laminated sheet steel. The principal parts of a transformer and their functions are given in table 3-1.

Table 3-1.-Principle Parts of a Transformer

Piece	Function
Core	Provides a path for the magnetic lines of flux
Primary winding	Receives the energy from the ac source
Secondary winding	Receives energy from the primary winding and delivers it to the load
Enclosure	Protects the above components from dirt, mositure, and mechanical damage

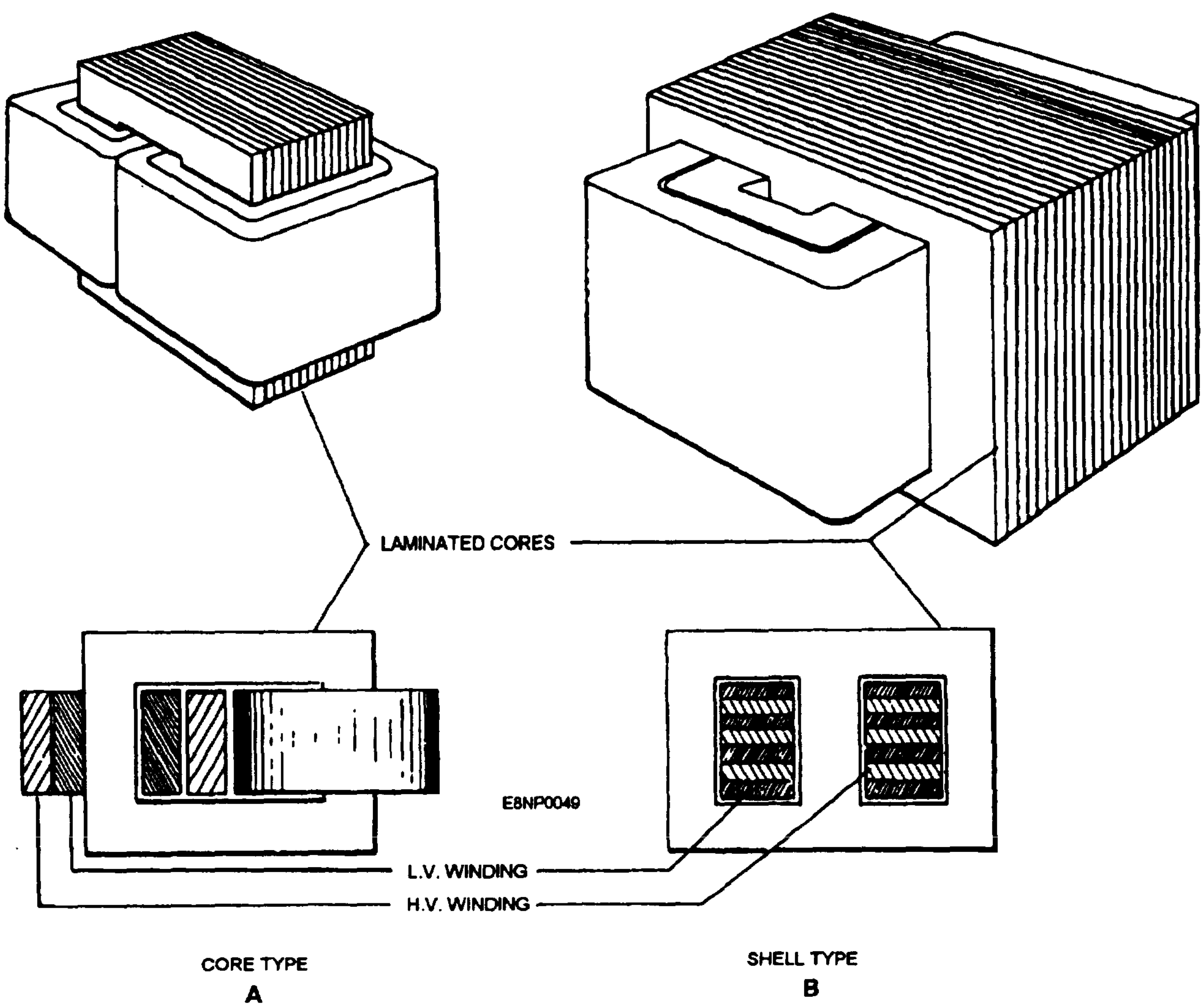


Figure 3-15.-Types of transformer construction: A. Core type; B. Shell type.

When a transformer is used to step up the voltage, the low-voltage winding is the primary. Conversely, when a transformer is used to step down the voltage, the high-voltage winding is the primary. The primary is always connected to the source of the power; the secondary is always connected to the load. A common practice is to refer to the windings as the primary and secondary rather than the high-voltage and low-voltage windings.

Two principal types of transformer construction are the core type and the shell type (fig. 3-15, views A and B). The cores are built of thin stamping of silicon steel. Eddy currents, generated in the core by the alternating flux as it cuts through the iron, are minimized by using thin laminations and by insulating adjacent laminations with insulting varnish. Hysteresis losses, caused by the friction developed between magnetic particles as they are rotated through each cycle of magnetization, are minimized by the use of a special grade of heat-treated, grain-oriented, silicon-steel laminations.

In the core type of transformer, copper windings surround the laminated iron core. In the shell-type of transformer, an iron core surrounds the copper windings. Distribution transformers are generally of the core type, whereas some of the largest power transformers are of the shell type.

Transformers are built in both single-phase and polyphase units (fig. 3-16). A three-phase transformer consists of separate insulated windings for the different phases, which are wound on a three-legged core capable of establishing three magnetic fluxes displaced 120° in time phase.

POLARITY MARKING OF POWER TRANSFORMERS

It is essential that all transformer windings be properly connected and that you have a basic understanding of the coding and the marking of transformer leads.

The leads of large power transformers, such as those used for lighting and public utilities, are marked with numbers, letters, or a combination of both. This type of

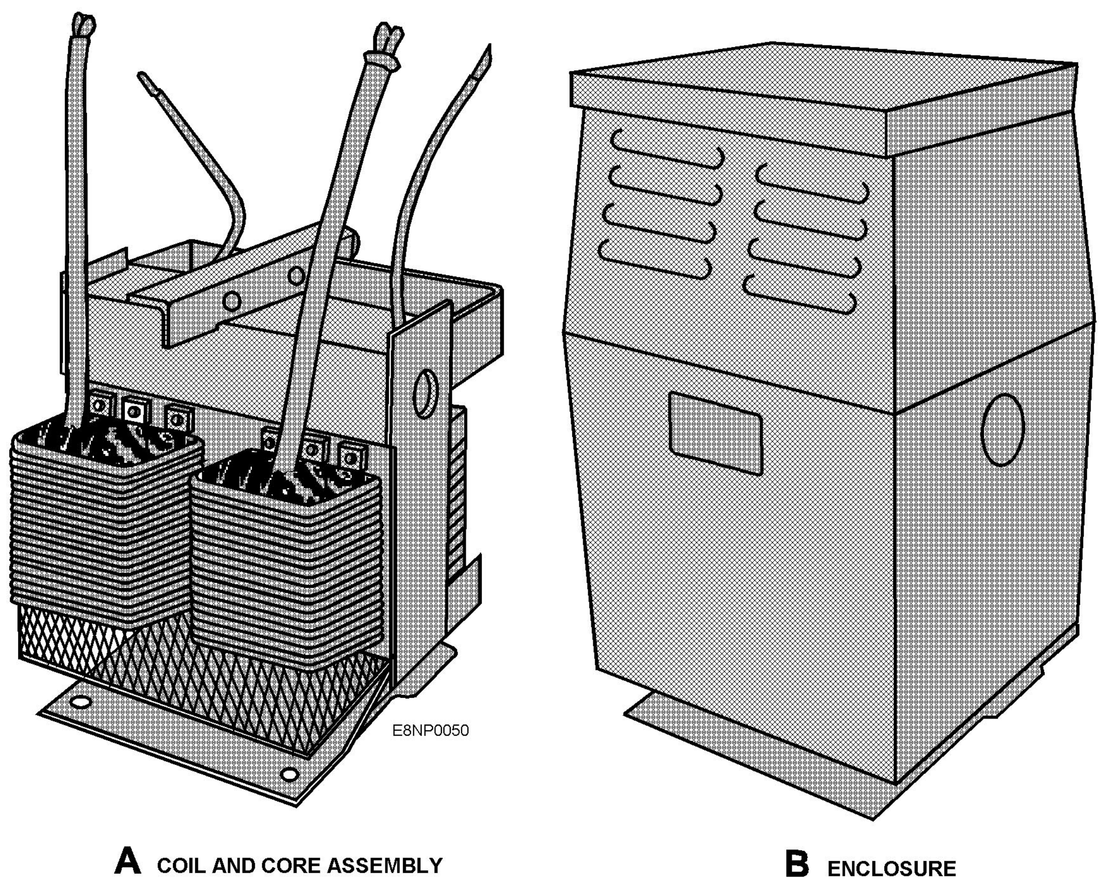


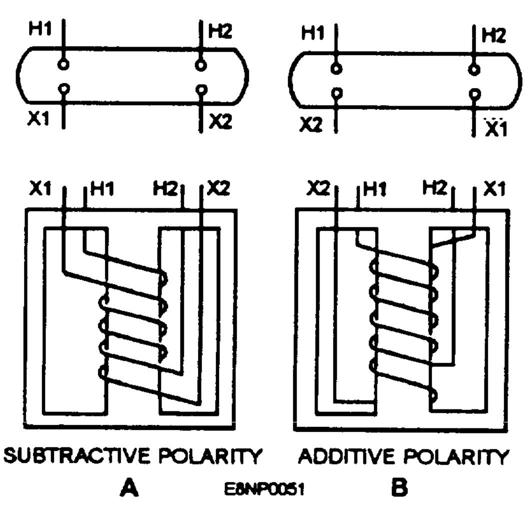
Figure 3-16.-Single-phase transformer A. Coil and core assembly B. Enclosure.

marking is shown in figure 3-17. Terminals for the high-voltage windings are marked H1, H2, H3, and so forth. The increasing numerical subscript designates an increasing voltage, denoting a higher voltage between H1 and H3 than the voltage between H1 and H2.

The secondary terminals are marked X1, X2, X3, and so forth Two types of markings maybe employed on the secondaries. When the H1 and X1 leads are brought out on the same side of the transformer (fig. 3-17, view A), the polarity is called subtractive. The reason this arrangement is called subtractive is if & H1 and X1 leads are connected and a reduced voltage is applied across the H1 and H2 leads, the resultant voltage that appears across the H2 and X2 leads in the series circuit formed by this connection will equal the difference in the voltages of the two windings. The voltage of the low-voltage winding opposes the high-voltage winding and subtracts from it; hence the term, ***subtractive polarity.***

When the H 1 and X1 leads are brought out on opposite corners of the transformer (fig. 3-17, view B), the polarity is additive. If the H1 and X2 leads are connected and a reduced voltage is applied across the H1 and H2 leads, the resultant voltage across the H2 and X1 leads in the series circuit formed by this connection will equal the sum of the voltages of the two windings. The voltage of the low-voltage winding aids the voltage of the high-voltage winding and adds to it, hence the term, ***additive polarity.***

Polarity markings do not indicate the internal voltage stress in the windings. They are useful; only in making external connections between transformers.



F'igure 3-17.-Polarity markings for large tramsformers: A. Subtractive polarity; B. Additive polarity.

400-HERTZ POWER DISTRIBUTION

In addition to the 60-Hz power supplied by the ship's service generators, ships also have 400-HZ systems. On some ships 400-Hz power is generated by motor-generator sets and distributed via special frequency switchboards (fig. 3-18) to the various 400-Hz equipment.

These motor generators supply power to ship's service special frequency switchboards. Figure 3-19 is a simplified line diagram of the 400-Hz ship's service bus tie interconnections on an older ship. The circuits being fed from the 400-HZ ship's service switchboards are deleted from the figure for simplicity.

Newer ships get their supply of 400-Hz power through the use of 60/400-HZ static converters. The 400-Hz system consists of four MBT's supplying 60-Hz power to four 60/400-Hz static frequency converters

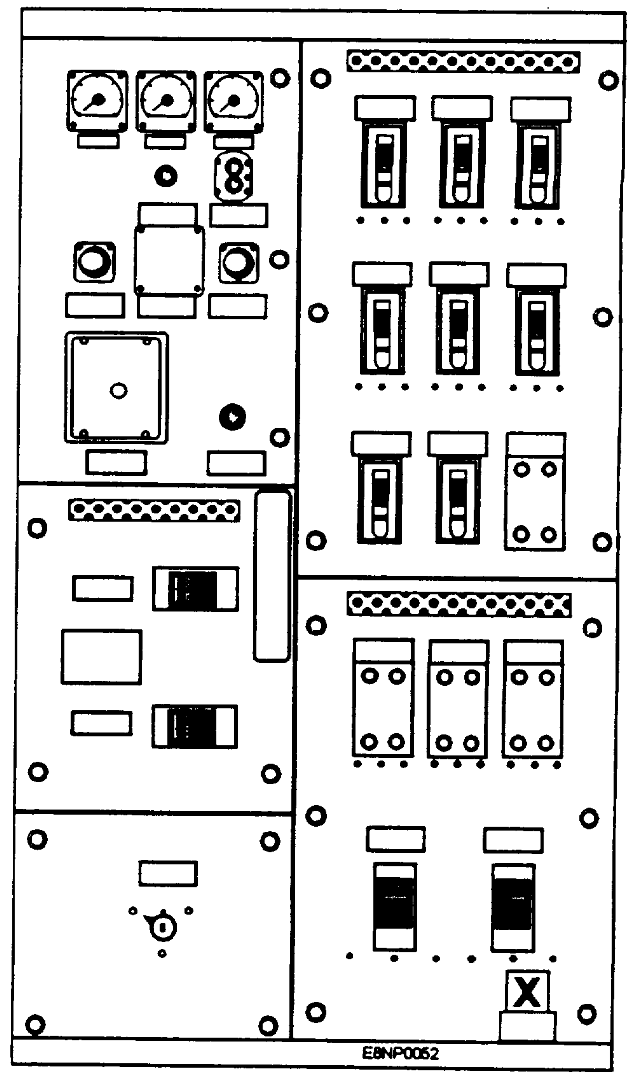


Figure 3-18.-400-Hz switchboard.

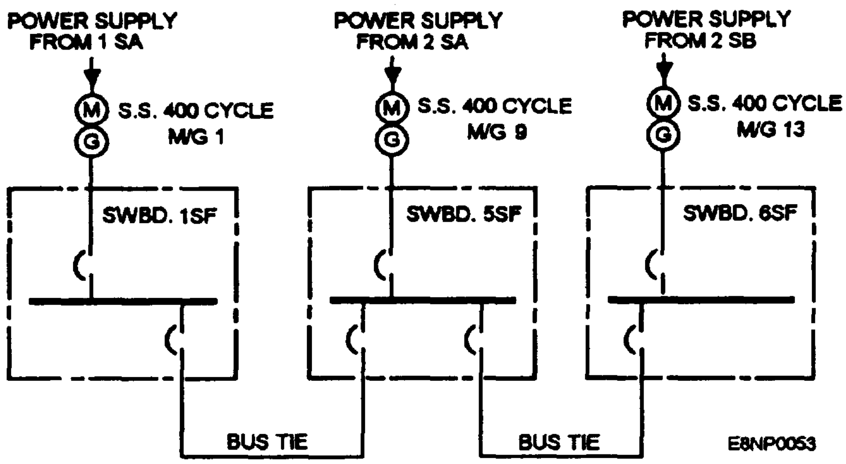


Figure 3-19.-Bus the connections on 400-Hz ship's service system.

(STC 1 thru STC 4). Each is rated at 150 KW at 0.8 power factor (fig. 3-20) and distributed to 400 Hz loads through two distribution switchboards, designated 1SF and 2SF.

Both distribution switchboards provide for centralized distribution of 450-volt, three-phase, 400-Hz power. Each switchboard is also capable of controlling and monitoring converter input, converter output, and bus tie circuit breakers.

CASUALTY POWER DISTRIBUTION SYSTEM

Damage to ship's service and emergency distribution systems in wartime led to the development of the casualty power system. This system provides the means for making temporary connections to vital circuits and equipment. The casualty power distribution system is limited to those facilitues necessary to keep the ship afloat and permit it to get out of the danger area. It also provides a limited amount of armament, such as weapons systems and their directors.

Optimum continuity of service is ensured in ships provided with ship's service, emergency, and casualty power distribution systems. If one generating plant should fail, a remote switchboard can be connected by the bus tie to supply power from the generator or generators that have not failed

If a circuit or switchboard fails, the vital loads can be transferred to an alternate feeder and source of ship's

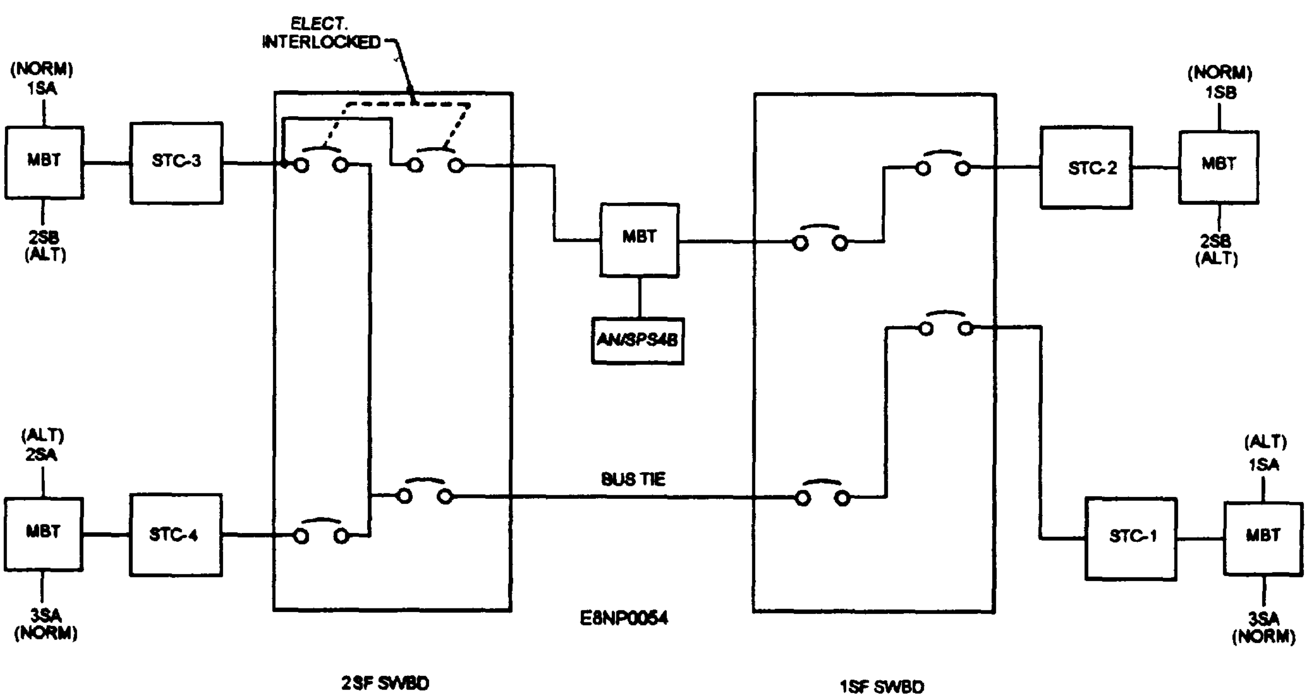


Figure 3-20.-400-Hz electric power distribution system.

service power by means of a transfer switch near the load.

If both the normal and alternate sources of the ship's service power fail because of a generator, switchboard, or feeder casualty, the vital auxiliaries can be shifted to an emergency feeder that receives power from the emergency switchboard.

If the ship's service and emergency circuits fail, temporary circuits can be rigged with the casualty power distribution system and used to supply power to vital auxiliaries if any of the ship's service or emergency generators can be operated. The casualty power system includes suitable lengths of portable cable stowed on racks throughout the ship. Permanently installed casualty power bulkhead terminals form an important part of the casualty power system (fig. 3-21). They are used for connecting the portable cables on opposite sides of bulkheads, so that power may be transmitted through compartments without loss of watertight integrity; also included are permanently installed riser terminals between decks.The vital equipment selected to receive casualty power will have a terminal box mounted on or near the equipment or panel concerned and connected in parallel with the normal feeder for the equipment.

Sources of supply for the casualty power system are provided at each ship's service and emergency generator switchboard. A casualty power riser terminal is installed on the back of the switchboard or switchgear group and connected to the buses through a 225- or 250-ampere AQB circuit breaker. This circuit breaker is connected between the generator circuit breaker and the generator disconnect links. By opening the disconnect links, you will isolate the generator from the switchboard. Then, it can be used exclusively for casualty power purposes.

RIGGING CASUALTY POWER

To eliminate the necessity of handling live cables and to reduce the hazards to personnel and equipment, definite procedures must be followed and safety precautions must be observed in rigging casualty power.

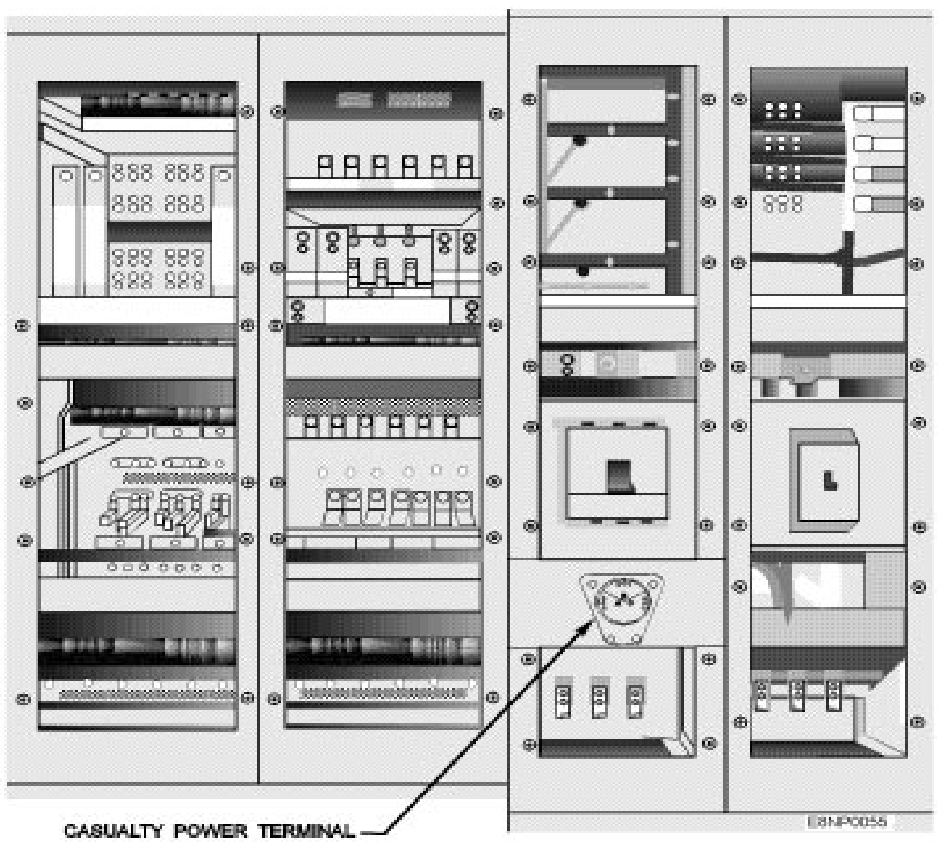


Figure 3-21.-Rear of switchboard showing casualty power terminal.

Only qualified Electrician's Mates should do the actual connecting; however, the portable cables may be laid out by other party personnel.The repair party electrician must wear rubber gloves, rubber boots, and stand on a rubber mat while making connections. Each casualty power riser or bulkhead terminal must be tested with a voltage tester before a connection can be made to the terminal. The duty of the repair party Electrician's Mate is to determine that all sources of power to the equipment concerned are de-energized before rigging casualty power. The portable cable connections for casualty power should always be made by first connecting the load and then working back to the source of power.

On large ships, casualty power runs involve more than one repair party. All repair parties should rig simultaneously, but the rule of "rig from load to source" should always be observed Each repair party must report its section rigged from riser or bulkhead terminal number to riser or bulkhead terminal number to damage control central.

In all instances of rigging and energizing any part of the casualty power system, only the damage control assistant, with the authority of the chief engineer, has the authority to order the system energized.

In making casualty power connections at a load where there are no circuit breakers or transfer switches to interrupt the incoming feeder cable, the load must be disconnected or cut at the equipment. It is quite possible that the feeder cable may be damaged by the casualty that caused the loss of power. A damaged cable, if energized, would probably trip the casualty power circuit breakers. If not disconnected, this incoming feeder cable may be re-energized, and present a hazard to personnel handling the casualty power cables.

The keep the phase sequence correct in ac systems, exercise care in making all connections. The riser terminals, bulkhead terminals, and portable cable ends are marked to identify the A-, B-, and C-phases. You can make the identification visually by color code. In the dark you can make the identification by feeling the bumps on the riser terminals or feeling the twine wrappings or O-rings installed on the cables.

Ordinarily, portable casualty power cables should be tied to the overhead. High-voltage signs should be attached at each connection and the information passed over the ship's 1MC system informing all hands to stand clear of the casualty power cables while energized.

AS previously stated, power panels supplying equipment designated for casualty power service will have a power terminal box mounted on the panel so that power may be fed into the panel. Remember that these panels can also be used as a source of power for the casualty power system should power still be available from the permanent feeder or feeders to the panel. Some judgment should be exercised, however, in the choice of panels to be used for supplying casualty power loads. Heavy loads should be connected to power panels having large incoming feeders for greater assurance that circuit breakers will not trip and that the cable will not become overheated. Current loading of casualty power cables is not considered excessive when you can grasp the cable by hand and it does not cause burning. Portable cable used in ac casualty power systems is Navy LSTHOF 42. Although the normal current carrying capacity of this cable is 93 amperes, its casualty rating is 200 amperes. Under normal conditions this cable will carry 200 amperes for 4 hours without damage to the cable. Cables maybe run in parallel to circuits that overload a single cable.

Recommended SAFE procedures to be used in rigging casualty power include the following:

- Upon report of loss of power, damage control central orders the repair party nearest the equipment concerned to investigate.
- The repair party Electrician's Mate of the investigating team immediately tests to determine if all sources of power to the equipment have been lost.
- Upon determining that all power is lost, the Electrician's Mate opens all supply switches to the equipment and reports to damage control central that power is lost to the equipment.
- Upon receiving a report of all power lost, damage control central requests main engine control to designate a source of casualty power for the equipment concerned. The request for a casualty power source may be made to the electrical officer on ships having a combined main engine control and damage control central or where the electrical officer is stationed in damage control central for the control of generators and power distribution.
- Main engine control or the electrical officer, as appropriate, informs damage control central of the casualty power source to be used (giving riser terminal number) and, at the same time, informs the Electrician's Mate on the appropriate switchboard that his or her board has been

designated as a source of casualty power to the riser terminal by number.

- Upon receiving this information, damage control central orders the repair parties concerned to rig casualty power from the equipment to the designated source.
- Repair parties rig casualty power and report each section completed to damage control central.
- After all sections have reported the rigging completed, damage control central requests the main engine control electrical officer to "energize casualty power."
- Upon receiving the request to energize, main engine control or the electrical officer directs the designated switchboard to "connect and energize casualty power," and to report compliance.
- The Electrician's Mate on the designated switchboard rigs the first cable from the source of the system, closes the casualty power circuit breaker, and reports casualty power energized to main engine control, then reports compliance to damage control central.

UNRIGGING CASUALTY POWER

Unrigging casualty power can be hazardous if not handled correctly. The steps to be taken to unrig casualty power lines are as follows:

1. Damage control central requests main engine control to de-energize the casualty power system.
2. Main engine control directs the designated switchboard to de-energize and disconnect casualty power, and to report compliance.
3. The Electrician's Mate at the switchboard opens the casualty power circuit breaker, unrigs both ends of the first portable cable, and reports "casualty power de-energized," to main engine control. Main engine control reports compliance to damage control central.
4, Upon receiving the de-energized reprt, damage control central orders casualty power disconnected at the equipment,
5. The repair party's Electrician's Mate disconnects both ends of the last portable cable in the system at the load and reports, when completed to damage control central.
6. Damage control central requests main engine control to energize normal circuits to the equipment and orders repair parties concerned to unrig and restore the remainder of the portable cables.
7. Main engine control directs the designated switchboard to energize all normal circuits to the equipment and to report compliance. Main engine control reports compliance to damage control central. The exercise is not considered completed until damage control central receives the report the equipment is operating on normal power and all portable cables are restored on their proper racks.

Speed is desirable in all casualty power operation; however, safety precautions must never be sacrificed to attain speed. A thorough knowledge of the casualty power system and frequent drills by all personnel involved are necessary for safe and expeditious results.

SHORE POWER

The number and locations of shore power connections vary on different types of ships. Shore power connections are provided at, or near, a suitable weather-deck location to which portable cables from the shore or from ships alongside can be connected to supply power for the ship's distribution system when the ship's service generators are not in operation. This connection also can be used to supply power from the ship's service generators to ships alongside.

Shore-power arrangements and hardware used on both ship and shore installations are so diversified that no specific installation instructions can be outlined in detail. Ashore installation that has one circuit breaker supplying a number of cable sets presents a particular hazard. In this case, you can verify phase rotation and phase orientation only by energizing all shore terminals. You should check phase rotation with only one set of cables installed. The latest designs have a single, 3-phase receptacle for ship and shine-power terminals. These receptacles are keyed in such a manner that phase rotation and orientation cannot be altered provided both the ship and shore use these receptacles, and the cables are not spliced. Phase orientation need not be checked before hookup. Systems that use 3-phase receptacles are normally designed so that interlocks on receptacles automatically trip associated circuit breakers whenever the cover of the receptacle is open, and a shore-power cable plug is not in place. However, you should still check voltage to these receptacles to ensure they are de-energized before installing the shore cables.

RIGGING SHORE POWER

The following procedures apply to the shore installation with a separate circuit breaker or disconnect for each set of cables and a single, 3-phase receptacle is not used. You should follow these basic instructions and procedures before and during connecting to shore power.

- Connect and disconnect shore power under the direct supervision of the electrical officer, a qualified leading electrician, and shore-activity personnel.
- Visually inspect shore-power cables for any sign of defects (such as cracks, bulges, and indications of overheating), thoroughly examine spliced cables, in particular, because improperly spliced cables are extremely dangerous. Strip lug-to-lug connection splices of insulation and check the connection for cleanliness, tightness, and good surface contact. Repair all defects and reinsulate all lugs before cables are placed in service. *Check* cables for insulation resistance using a 500-volt Megger (megohmmeter). Insulation resistance readings should meet requirements of Naval *Ships' Technical Manual, "Electric Plant General,"* Chapter 300. Check the resistance between phases and between each phase and ground. For purposes of the test, shore ground should be the enclosure that houses shore-power terminals or receptacles. On ships, ground should be the hull of the ship or any metal extension of the hull. During the physical inspection and Megger tests, check the phase identification of the cables. Pay particular attention to cables that have been spliced to ensure that the phases of the cables are continuous and have not been altered at the splices.
- Tag with high-voltage signs and, if possible, rope off the work area surrounding the ship's shore-power terminal box or receptacle. This box or receptacle is often exposed to elements, and any moisture present can cause a serious problem. With the ship's shore-power breaker tagged in the open position, disconnect all equipment (such as meters and indicator lights) that could be damaged by a Megger test or cause a false wading. Test the terminals in the ship's shine-power terminal box or receptacle with a voltage tester to ensure they are de-energized Next, with a 500-volt Megger, test the insulation resistance between terminals and from each terminal to ground.
- Lay out the cable between the supplying shore-power outlet and the ship's shore-power terminal box or receptacle. Ensure that the cable is of sufficient length to allow enough slack for the rise and fall of the tide, but not of such length as to permit the cable to dip into the water orbecome wedged between the ship and pier. Do not permit cables to rest on sharp or ragged objects, such as gunwales. Avoid sharp bends. Lay cables in wood saddles or wrap them in canvas. Raise splices and connectors from the deck or pier for protection against water contamination. Neatly fake out excess cable to minimize damage from vehicle and pedestrian movements.
- Connect the shore cables to the ship's shore-power terminals according to phase or polarity markings in the box and on the cables.
- Ensure correct phase orientation (phase relationship) by checking color coding or phase identification markings on cables. Reconfirm correct phase identification by meggering between like phases of cables. Cables that give a zero indication will have the same phase relationship. After meggering, reconnect any disconnected equipment.
- With a voltmeter, check to ensure that the shore-power terminals are de-energized.
- Connect the shore-power cable to the terminals.
- Check for proper phase rotation either by alternately energizing shore-power receptacles, one at a time, and observing the ship phase rotation indicator mounted in the ship's service switchboard or use a portable meter connected to an appropriate bus. After checking phase rotation, de-energize each source shore-power receptacle before energizing the next receptacle for the phase rotation check.
- Energize all source shore-power terminals or receptacles and proceed with the transfer of electrical load to shore power following engineering department operating instructions. Instructions will vary depending upon whether or not the ship is equipped to synchronize with shore power.

After cables are carrying the load, inspect all connections to locate any possible overheating resulting from poor connections or reduced copper in the circuit. Inspect cable ends at the point of connection for heavy strain or overheating.

Shore-power cables are rated at 400 amperes. Check switchboard meters to ensure that the total load on shore-power cables does not exceed the combined rating of shore-power cables. Total shore-power load in amperes should be no more than 400 times the number of shore-power, 3-phase cables connected per phase.

PHASE-SEQUENCE INDICATOR

A phase-sequence indicator is used when you are connecting shore-power to your ship to ensure proper phase relationship between ship power and shore power.

An approved type of phase-sequence indicator (fig. 3-22) has a miniature, 3-phase induction motor and three leads with insulated clips attached to the ends. Each lead is labeled A, B, and C. The miniature motor can be started by a momentary contact switch. This switch is mounted in the insulated case with a switch button protruding out the front of the case to close the switch. When the motor starts turning, you can tell its direction of rotation through the three ports in the front of the case. Clockwise rotation would indicate correct phase sequence. You can stop the motor by releasing the momentary contact switch button.

UNRIGGING SHORE POWER

When disconnecting shore power, observe the same safety precautions outlined in the connecting sequence except for those regarding meggering cables and checking phase orientation and phase rotation. Again, tag shore-power breakers and disconnect following safety procedures. Determine that the shore-power busing and cables are de-energized by using a voltage tester that has just been checked with a known energized power source.

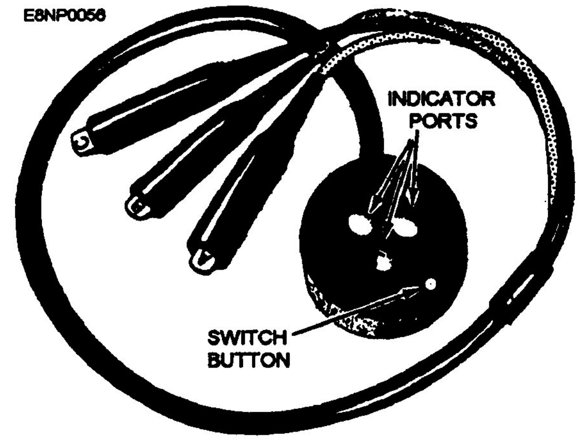


Figure 3-22.-Phase-sequence indicator.

NOTE: Moving energized shore-power cables is prohibited.

SUMMARY

In this chapter you have been introduced to the ac power electrical distributions system. We have studied the electrical distribution system, bus transfer switches, ship's service switchboards, ac generators, transformers, 400-Hz power distribution, casualty power, and shore power. Possessing a good understanding of the ac power distribution within your assigned spaces, will greatly enhance your ability to restore ac power to your equipment in the event of its loss or tore-configure to alternate, casualty, or shore power.